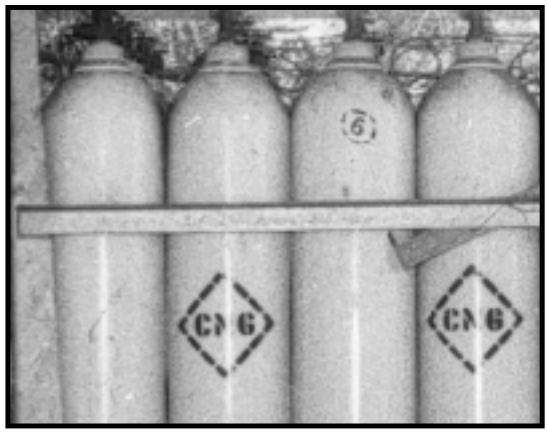

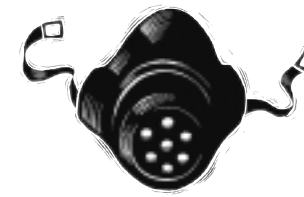

Safety of CNG Buses in Delhi

FINDINGS AND RECOMMENDATIONS

by

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August 9, 2002

CENTRE FOR SCIENCE AND ENVIRONMENT, NEW DELHI

Right to clean air campaign

CSE blew the lid on smog and smogmakers in 1996 in its book *Slow murder: The deadly story of vehicular pollution in India*. The study found that the problem of vehicular pollution in India was the result of a combination of outdated engine technology, poor fuel quality, defective transportation planning and bad maintenance of vehicles on road.

CSE exposed that the government was indulging in the game of blaming the victims of air pollution by forcing on them a system of pollution under control certificates. The hype over this periodic drive to test tailpipe emissions of cars in the absence of strong action in other areas, was cosmetic and diverted public attention from more serious issues of technology and transportation planning. But the connection between poor urban air quality and multiple factors such as these eluded most Indian citizens. To help citizens see through the smokescreen of pollution, to understand this vital **CONNECTION,** and protect public health the *Right To Clean Air Campaign* was launched in November 1996. Since then we are consistently campaigning to:

- **improve the decision-making processes related to air quality planning**
- **build up pressure on the government for more transparent policy mechanism**
- **raise public awareness about poor urban air quality and risks to public health**

If you agree with us, remember to give us your support.

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“This programme can serve as an outstanding example for other cities and nations of a successful transition to CNG.”

WHY THIS STUDY?

In this sequel to last year's technical evaluation of the CNG bus technology we attempt another assessment. This study once again confirms that maintaining the quality of Delhi's CNG programme is an even greater challenge than introducing CNG technology in the city. The process is still riddled with problems. The reason is simple. The government had delayed the firming up of rules and regulations for implementing the CNG programme as mandated by the Supreme Court. Inert official response to meet the challenges of introducing a new technology could destroy this crucial strategy to control particulate emissions in Delhi.

Alarmed at the government's laxity, we decided to examine the details of the CNG programme and put it under intense scrutiny to look for obstacles that prevent a smooth transition. We stumbled upon many problems: weak regulations on safety and emissions, inadequate infrastructure for safety and fitness inspection for CNG buses, ad hoc procedures for the conversion of old buses, and other technical snags afflicting the new programme that has no clear roadmap. We realised there was a pressing need for competent technical advice to push for appropriate policies, chart new action plans and re-orient strategies based on the lessons learnt. We feared that if we did not do this now the programme could easily slide back.

Last year, three experts with commendable expertise in the field of CNG as well as heavy-duty diesel technology — Christopher Weaver, President, Engine, Fuel, and Emissions Engineering, Inc., USA; Lennart Erlandsson of Motor Testing Centre, Sweden; and Frank Dursbeck, formerly with TUV Rheinland Sicherheit Und Umweltschutz GMBH, Germany — were invited by us to undertake the first assessment. The experts' study coincided with the introduction of CNG buses in the capital amidst the furor raised about their safety and performance. The government's response here, too, was a mixture of apathy and misdirection.

Their study confirmed to us that the basic prerequisites for implementing the CNG bus programme were in place, although we realized some improvements in emissions and safety features to make the technology safe for operation were needed. In particular, the study identified the inadequate emission norms and safety guidelines, convoluted certification procedures, and the lack of stringent inspection systems.

Lennart Erlandsson and Christopher Weaver returned to the city in June this year for a follow-up study to identify fresh problems that have cropped up as a result of the unprecedented expansion in the scale of the city's CNG programme. The number of CNG buses rapidly increased from 900 in May 2001 to nearly 7000 in Delhi, representing perhaps the largest city CNG bus fleet in the world.

Experts have reaffirmed that " in any largescale deployment of new technology, operational difficulties and new safety concerns are likely to occur. But this programme is an accomplishment of which the world will take notice."

How do such studies help?

The first study facilitated a process of critical re-examination and paved the way for important policy changes. The key recommendations of the first evaluation became the basis of the report on safety standards for CNG buses submitted in June 2001 by the Environment Pollution (Prevention and Control) Authority (EPCA), the advisory committee to the Supreme Court of India. As a result, the Ministry of Road Transport and Highways revised the rules for emissions, safety and inspection systems for CNG vehicles on November 19, 2001.

The new gazette notification introduced Euro II emissions standards for all new CNG buses. It also strictly mandated Euro I emissions standards for converted buses, while rejecting the earlier rule of allowing older diesel buses to continue to meet the same emissions standards in force as the year of manufacture even after converting to CNG. The notification upgraded the existing safety standards to include AIS 028, the safety code of practice for CNG vehicles and made compulsory the inspection for all CNG buses before and after operation, while firmly directing that all engine-converters obtain a new type approval for each separate diesel engine model they seek to retrofit.

However, many problems remained unresolved. Twelve CNG bus fire incidents were reported last year, which neither the industry nor the government could explain to assuage public fears. It became evident that though new safety guidelines and inspection requirements were in place, their enforcement was slated only for November 2002 — a delay of a whole year after its notification. The government, once again, proved to be completely unable to keep pace with the directions of the Supreme Court to move public transport in Delhi to CNG.

To plug the delays in the implementation of the CNG programme, the apex Court had further directed the phasing in of 800 CNG buses every month from May 2002, onwards till such time as diesel buses were replaced. But this meant renewal for the entire fleet on the basis of the older and extremely inadequate rules. Worse, these buses would also be introduced without proper inspection. The quality of the CNG conversion programme stood in danger of being compromised, as it would not be able to accommodate the designed improvements.

It was, therefore, vital for us to quickly identify the cause of fire incidents and get the government to enforce new rules with immediate effect. The experts

EXPERTS' PROFILE

Christopher S. Weaver
President, Engine, Fuel, and Emissions Engineering, Inc., Sacramento, California

Christopher S. Weaver is an expert on emissions and technology for heavy-duty diesel and natural gas engines. He has assessed emissions and other characteristics of natural gas engines using all three fundamental technology types -- spark ignition with a stoichiometric or slightly rich mixture, spark ignition with a lean mixture, and dual fuel — for application in various countries, including Chile, Mexico, Brazil, Thailand, and the US. He has extensively studied the technology, emissions, and in-use service experience of heavy-duty natural gas engines produced in the US and Europe. He has also studied fuel supply issues, costs and technical issues involved in supplying compressed natural gas and liquefied natural gas. He has also assessed issues in storing and using natural gas on-board the vehicle. He has helped the Egyptian government develop technical specifications for CNG buses to be purchased for Cairo.

Lennart Erlandsson
Motor Test Centre AB, Sweden

As a member of one of Europe's largest Motor Testing Centers (MTC Sweden), Lennart Erlandsson is involved in many activities related to CNG buses. He has worked in projects in Santiago, Chile, to support the introduction of CNG buses for urban transportation. He has studied various technical solutions and has also conducted tests of buses intended for Santiago using different test cycles. He has also evaluated CNG buses as part of a project in Bangkok, Thailand. He has investigated issues arising from dedicated CNG engines and the conversion of old diesel engines to CNG. In Tehran, Iran, Lennart Erlandsson has worked to introduce new CNG buses and retrofitting old chassis with new gas engines and has assessed various conversion possibilities. He has been advising the authorities in Tehran on the country's CNG programme. He has examined possibilities of developing different systems used for CNG engines.

investigated and compiled their second report after extensive consultation with concerned agencies, including bus manufacturers Tata Engineering and Ashok Leyland, Delhi Transport Corporation, Automotive Research Association of India, association of conversion agencies, Ministry of Road Transport and Highways, Burari Inspection Centre, the State Transport Authority, and Indraprastha Gas Ltd. The experts also made extensive site visits.

This second evaluation has very clearly identified operational difficulties and addressed fresh safety concerns. It has uncovered lapses and compromises in safety features in some buses as a result of weak inspection systems, stating that inspectors in Delhi did not know what to check and how to assess whether a vehicle complied with the corresponding type approval.

In view of the cursory attention paid to inspection and safety norms, experts have made several recommendations that include: improving the institutional framework for coordinated action, firming up inspection requirements to ensure compliance with safety regulations, and training needs for capacity building. The experts' study argues for institutional arrangements being put in place to mitigate current safety problems — as well as those that may arise in the future. The experts conclude that

a number of problems have been identified, diagnosed and many of these are already on the way to solution.

This study holds special relevance for us as it has prodded us to initiate swift, corrective action. More importantly, it has prompted us to draw the attention of the Supreme Court to its basic findings, recommendations and concerns and also bring to public notice the government's negligence in not establishing appropriate inspection and testing facilities for monitoring and enforcement of safety standards for CNG buses.

Taking note of these concerns, the Supreme Court ruled on July 29, 2002:

> *"There is no reason as to why unsafe vehicles, which do not meet the safety norms should be allowed to ply on the road. We, therefore, direct that with effect from 5th August, 2002, no retro-fitted or converted CNG bus will be allowed to ply unless and until the Director, Transport Department, NCT of Delhi is satisfied and certified that the vehicles confirmed with the safety norms of 19th November, 2001."*

This move led the Delhi government to defer all further registration of CNG buses, both new and converted, and make pre-registration inspection mandatory from August 5, 2002. Hectic activities soon followed to enable all concerned agencies to jointly institute an independent inspection system specially designed for CNG buses in Delhi. CNG buses that are already on road will also be recalled in phases for inspection and sent for remedial changes where needed. We hope we are on our way to tracking and resolving most of the problems to successfully establish the programme.

We would like to take this opportunity to express our gratitude to all agencies that have cooperated with our experts. This study would not have been possible without financial support from the Swedish International Development Agency (SIDA). We wish to offer them our sincere thanks.

We hope that this series of independent technical evaluations will pave the way for appropriate legislation, lend clear policy directions, aid in capacity building and bolster consumer confidence in the CNG programme.

Right to Clean Air Campaign **August 9, 2002**
Centre for Science and Environment
New Delhi

1. INTRODUCTION

On July 28, 1998, the Supreme Court of India ordered measures to be taken against air pollution from road traffic in the National Capital Region (NCR), which includes the National Capital Territory (NCT) of Delhi[i]. The Court's order included the following directions to the Government of the NCR:

1. Replacement of all pre-1990 autos and taxis with new vehicles using clean fuels by 31.3.2000.
2. Financial incentives for replacement of all post-1990 autos and taxis with new vehicles on clean fuels by 31.3.2001.
3. No buses more than eight years old to ply except on CNG or other clean fuels.
4. Entire city bus fleet (DTC and private) to be steadily converted to single fuel mode on CNG by 31.3.2001.
5. Gas Authority of India Ltd. to expand its CNG dispensing capacity from 9 stations to 80 by 31.3.2001.
6. Automatic inspection and maintenance facilities to be set up for commercial vehicles in the first phase, immediately
7. Comprehensive I/M programme to be started by transport department & private sector by 31.3.2000

The first set of orders on replacement of pre 1990 autos and taxis and eight year old buses with CNG vehicles have already been enforced. This effectively means that buses more than eight years old cannot operate in the NCR unless powered by CNG. So after April 1, 2000 all diesel buses more than eight years old were taken off the road in Delhi.

The order to move the entire bus fleet to dedicated operation on CNG was not fully implemented by March 31, 2001 as the Court had ordered. To avoid a massive shutdown of bus services, the Court, on March 26, granted a conditional extension of the compliance deadline until September 30, 2001. This deadline was later extended to January 31, 2002. In the meantime, diesel buses were allowed to ply if their owners could demonstrate that they had placed a firm order either for the same number of new CNG buses or for conversion/retrofitment of their old buses to operate on CNG.

Despite (or because of) the repeated extensions, most private bus owners still failed to comply with the Court order. Many bus owners continued to operate diesel buses on the basis of having ordered a CNG bus, but then failed to accept delivery of the CNG bus chassis once it was ready. Therefore, the Court, on April 5, 2002 issued a further order that all bus owners who had placed orders for new bus chassis but had not yet taken delivery must do so within two weeks or see their permits to operate cancelled.At the same time, the Court imposed a fine of Rs. 500 per day per

bus on bus owners who continued to ply diesel buses, increasing to Rs. 1000 per day after 30 days.The Government of the NCR was ordered to phase out 800 diesel buses per month, beginning May 1, 2002.The Central Government was also ordered to make available adequate CNG to supply the buses and other CNG vehicles, and to prepare a scheme with a time schedule for the supply of CNG to other highly polluted cities of India.

The total number of public transport vehicles using CNG on the road in Delhi as of April, 2002 were as follows, according to data provided by Indraprastha Gas Limited (IGL).

Table 1: Number of CNG vehicles in August 2002

Vehicle Type	No of vehicles on the road
Delhi Transport Corporation buses	2,123
Private buses	4,688
Rural transport vehicles (small buses)	3,423
Taxis	5,973
Three-wheelers	43,156

Source: State Transport Authority, August, 2002

As expected during the deployment of a new technology, operational deficiencies and safety issues have surfaced

Approximately 3,000 diesel buses also continued in operation in April.However, the Court's order imposing monetary penalties for continued diesel operation seems to have overcome the resistance by the remaining bus owners.We were informed by Indraprastha Gas Ltd. that — as of late May — more than 4,688 private CNG buses were plying, while the number of diesel buses in operation had fallen to about 1,300. Companies offering conversion of diesel buses to CNG also reported that demand for their services increased enormously following the Court's order.

In May 2001, the Centre for Science and Environment contracted with us and another consultant, Frank Dursbeck of Germany to review and assess the status of the CNG conversion programme of the Delhi bus fleet.Our report at that time[ii] concluded that the CNG program was basically on track, and "poised for outstanding success". It also made a number of recommendations for improving the program, many of which have been carried out.

In the year that has passed since our previous report on Delhi's CNG programme, the operating CNG bus fleet has grown from about 900 to about 6,811; with comparable increases in the numbers of other vehicles operating on CNG. As might be expected during the widespread deployment of a new technology, a number of operational deficiencies and safety issues have surfaced during that time.In particular, public concern has been raised by a series of fires in CNG buses. The Centre for Science and Environment therefore requested us to revisit the issues addressed in our 2001 report, with particular attention to safety of CNG buses.

2. SCOPE OF WORK

We were requested to undertake an assessment of the safety aspects of CNG technology as employed in Delhi. This assessment was to include both new and conversion technologies, with particular reference to the technologies employed in buses.As part of this assessment, we were requested to visit the concerned agencies, workshops and research agencies to observe the situation and learn their

concerns and operating experience.We also reviewed the safety recommendations from our 2001 report, and the degree to which they have been implemented in the intervening year.Additional related questions and issues were identified during the course of the study, and these are also addressed in this report.

3. ACTIVITIES AND ORGANISATIONS CONTACTED

Between May 29 and June 6, 2002 we carried out numerous visits to relevant organisations in order to assess the CNG programme and safety issues. We visited or met with representatives of the companies following and organizations:

Bus Manufacturers
Ashok Leyland Limited
Tata Engineering (Telco)

Bus Converters
DD Motors
VIP Buildcon
Rare Technologies

Government regulatory agencies
Ministry of Road Transport and Highways
State Transport Authority (STA)
Burari Inspection Centre
Delhi Transport Ministry

Certification Agency
Automotive Research Association of India (ARAI)

Natural Gas Distribution Company
Indraprastha Gas Limited (IGL)

State Transportation Company
Delhi Transport Corporation (DTC)

The agenda was prepared and organised by the CSE staff. We wish to express our appreciation and gratitude for the time spent and courtesies shown to us by these various organisations.

Given the scope and speed of the changes ordered, it'd have been surprising if some problems and deficiencies had not been experienced

4. FINDINGS AND RECOMMENDATIONS

In our report of May, 2001, we and our colleague, Frank Dursbeck, stated our unanimous view that "... **the principal programme elements required to implement the CNG bus programme in Delhi appear to be in place, and that this programme appears poised for outstanding success**. **This is an accomplishment of which the world will take notice, and in which the principal agencies and persons involved in the CNG programme can rightly take great pride. This programme can serve as an outstanding example for other cities and nations of a successful transition to CNG."** One year later, we reaffirm this conclusion.

The Honourable Supreme Court's order to improve air quality in Delhi called for a change in transportation vehicles and fuelling infrastructure that is without precedent in history. Given the scope and speed of the changes ordered, it would have been surprising indeed if some problems, deficiencies, and disorganisation had not been experienced during the transition. These difficulties were exacerbated

by widespread uncertainty over the enforcement of the court order — much of it created through confusing and contradictory statements by different branches of the Government itself. This uncertainty led to extensive non-compliance during the transition period, followed by a frantic rush to comply once the April, 2002 Court orders took effect.

In any large scale deployment of new technology, operational difficulties and new safety concerns are likely to occur. Such has been the experience with CNG buses in Delhi. A number of problems have been identified and diagnosed, and many of these are already on the way to solution. Some problems remain to be solved, however, and further measures are needed to assure the continuing safety of CNG vehicles over their full useful lives. Institutional arrangements need to be put in place to ensure that the remaining safety problems — as well as any that may develop in the future — are effectively identified, diagnosed, and solved, and that these solutions are actually implemented.

4.1. Air Quality and Health Benefits

"Our observations leave no doubt that diesel buses were responsible for a very substantial part of the fine PM problem in Delhi"

No discussion of the safety of the CNG bus program would be complete without a discussion of the grave health risks that the program is designed to reduce. Diesel exhaust emission has been identified to contain cancer-causing substances — accounting for about 70% of all of the cancer risks due to air pollution in California. Exposure to fine particulate matter such as diesel PM has also been found to be the main source of air-pollution related deaths and illnesses in cities as varied as Los Angeles and Bangkok.

The annual average concentration of respirable particulate matter (PM10) in Delhi in 2001 was approximately 180 micrograms per cubic meter according to measurements reported by the Central Pollution Control Board. According to a World Bank summary of studies done in a number of developing-country cities[iii], the risk of death from non-accidental causes increases by approximately one percent for each 10 micrograms per cubic meter of respirable PM. Accordingly, and as per World Bank studies lowering ambient PM10 to the WHO recommended target level of 40 microgrammes per cum would help avoid 9,000 premature deaths annually.

Diesel vehicles predominantly produce fine particulate matter (PM2.5), which is the fraction of the PM10 that is most dangerous for human health. Because of the absence of emission measurements and a comprehensive emissions inventory, it is not possible to estimate accurately how much of the high ambient concentration of PM10 and PM2.5 in Delhi is due to buses and other vehicular sources. However, our observations on the street leave no doubt that diesel vehicles - and especially diesel buses - were responsible for a very substantial part of the fine PM problem in Delhi. The change from diesel to CNG buses has noticeably reduced public exposure to diesel smoke and particulate matter on the roads.

Research to quantify the vehicular contribution to air pollution, and to identify and control other sources of fine PM and PM precursor emissions should be a high priority for Delhi. We recommend that this research include receptor studies (chemical analysis of ambient PM samples to apportion responsibility among different sources) and the development of an accurate emissions inventory — especially of vehicular emissions.

4.2. First Year's Operating Experience: Safety Issues and Lessons Learnt

Government authorities and the general public have rightly been concerned by a

series of incidents in which CNG buses have been involved in fires caused or aggravated by the release of natural gas from the fuel system. Prior to our arrival in Delhi, we were provided by CSE with a list of ten such incidents. This list is reproduced in Table 2. Fortunately, the number of persons killed and injured in these fires has been small. We were informed by IGL that only one person — a passer-by — has been killed in all of the fires to date.

As Table 2 shows, all of the bus fires for which information was available appear to have resulted from large, sudden releases of gas from the CNG fuel system. This appears also to have been the case with the fires in the two Ashok Leyland buses, for which no data was given in Table 2.

Natural gas is lighter than air, and mixtures of air and natural gas are inflammable only in a fairly narrow range of gas concentrations between 5% and 15% by volume. Thus, small leaks of natural gas are unlikely to result in fires, since the gas normally disperses upward before reaching a flammable concentration. However, any large, sudden release of gas from a vehicle fuel system creates a substantial fire risk, since

Table 2: Fires involving CNG buses in Delhi

Company	Date	Distance covered (km)	Observations	Reason
Telco	April 2001	4000	1. One gas pipeline from cylinder on right hand side found detached at the cylinder end 2. Battery positive cable found short circuited and broken. Rerouted over the gear shift lever 3. Battery cut off switch was not installed	Gas pipe disconnection
Telco	January 2001	5500	1. Battery positive cable found short circuited and broken. Rerouted over the gear shift lever 2. Battery cut off switch was not installed 3. All high pressure pipes found intact 4. One open end spanner was found on the engine	Gas pipe disconnection
Telco	February 2001	11000	1. Battery positive cable found short circuited and broken. Rerouted over the gear shift lever 2. Battery cut off switch was not installed 3. Cylinder on LHS bullnose connector found loose	Gas pipe disconnection
Telco	June 2001	6550	Right hand side top cylinder pipe came out of T-ferrule and bent towards left hand side wall	Gas pipe disconnection
Telco	March 2001	26537	Left hand side inner gas cylinder bull nose connector stem found broken from T	Accident due to driver's error
Telco	January 2001	4440	1. One burst disk valve missing 2. Burst disk valve on RHS found handloose 3. Left hand side top cylinder burst disc valve was tight	Related to filling operation
Telco	June 2001	24723	RHS bottom outer bull nose connector stem broken from T	Accident due to driver's error
Telco	February 2001	63000	1. Left hand side cylinders dislodged from chassis 2. Bottom cylinder outer bull nose connector stem broken from T	Structural failures
Ashok Leyland	—	NA	NA Related to filling operation	
Ashok Leyland	—	NA	NA Related to filling operation	

the mixing of gas with the surrounding air results in the occurrence of air-to-gas ratios in the flammable range over a substantial volume of space in the vicinity of the vehicle. A spark or flame anywhere in this volume can ignite a fire. This risk is greater with a bus than with a smaller vehicle, since the large volume of fuel stored on a bus increases the volume of the inflammable mixture, and the structure of the bus body can trap gas underneath where it is exposed to ignition sources. The precise dimensions and extent of the flammable volume depend on the amount of gas released and on the surroundings and wind conditions at the time of release, which are not readily controlled. To further complicate the situation, it can be difficult to see the flame from the burning gas under daylight conditions.

Our investigation shows that the ten bus fire incidents reported to us are only the tip of a much larger iceberg of large, sudden releases of gas during bus operations. While the great majority of these releases do not result in a fire, any such release has the *potential* to do so. All such releases should therefore be tracked and investigated in order to identify the root cause or causes, so that problems can be identified and solutions implemented where appropriate. At present, root-cause investigations of sudden gas releases are not being done unless such releases result in fires. A key recommendation of this study is that an independent safety agency assess the root causes of *every* large uncontrolled release of gas, and not only the ones that result in fires or other damage.

Root-cause investigations of sudden gas releases are not being done. Every large uncontrolled release of gas, should be assessed

From our discussions with the parties involved, the gas releases that have resulted in bus fires appear to have been due to three main root causes:

1. *Insufficient flexibility in the high-pressure gas piping* on new Telco CNG bus chassis produced during 2001, which resulted in some high-pressure gas pipes being pulled out of their fittings while the bus was in motion;
2. *Failure of "burst disks"* (pressure relief devices or PRDs), usually while the vehicle is being refuelled; and
3. *Damage to the high-pressure gas piping* as a result of accidents

The problem of insufficient flexibility on the new Telco CNG bus chassis appears to have been resolved. Telco has informed us that all of the affected 2001 production have been retrofit with more-flexible, smaller-diameter (0.25 inch or 6 mm) piping to correct the problem, and we saw a number of buses that had been so retrofitted. Discussions with bus users confirm that this problem has not occurred recently.

Similarly, a problem of piping failure due to lack of flexibility is likely to occur in some converted diesel buses in the future. During our visit to the Burari inspection centre, we observed similarl inflexible arrangements of the high-pressure gas piping on newly converted buses from two different bus conversion companies that had been presented to the STA for inspection. In our opinion, there is a good chance that these converted buses may suffer piping failures similar to those experienced by the Telco CNG chassis. The piping installation on these buses appeared not to conform to the requirements of AIS 028 – specifically, to the requirement for use of stress loops or U-bends, and for distance between supports for the high-pressure tubing. Effective enforcement of AIS 028 requirements as part of the inspection process would likely correct the problem. As further discussed in Section 4.6, we recommend that fitness inspections for buses begin requiring compliance with AIS 028 immediately.

Pressure relief devices (PRDs) are the main cause of uncontrolled gas releases at present. The purpose of the PRD is to protect against the possible explosion of a CNG cylinder if it were involved in a fire. In these conditions, the increasing

temperature of the gas would increase the pressure inside the cylinder, while reducing the strength of the cylinder walls. The PRD is designed to fail and release the cylinder contents before the cylinder walls rupture. PRDs normally incorporate either "burst disks" designed to fail and release gas at a given pressure, or "fusible" elements that are designed to soften and release gas at a given temperature. Some combination designs incorporate both elements. Until recently, nearly all CNG buses in Delhi were equipped with burst-disk type PRDs. Because of the problems with these devices, both the chassis manufacturers have recently switched to thermal PRDs containing fusible elements for buses they are now manufacturing.

Uncontrolled gas release due to the failure of "burst-disk" type PRDs is regrettably common. Attendants both at DTC stations and at public CNG fuelling stations catering to buses estimated rates of burst-disk failure ranging from one or two per refuelling station per week to one or two per *day*, with the latter being the more common estimate. If this is even partly correct, it would amount to at least two percent of the bus fleet suffering failures *each week*, or an average of roughly one PRD failure per bus per year. Burst disk failures are apparently so common that it has become routine for station attendants to minimise the volume of gas released by closing the shutoff valve for the affected cylinder. Given the frightening noise of the high-pressure gas release and the real risk of fire, this action requires considerable courage.

The rate of failure of PRDs in Delhi buses is far higher than has been experienced in other CNG bus fleets, and appears to reflect errors either in the specification or in the manufacture of the burst disks. US bus fleets in the 1990s suffered a number of PRD failures due to problems with one specific type of PRD. This led to an industry review of PRD requirements, and to the adoption of a new American National Standard for PRDs, ANSI-IAS PRD 1-1998, and an amendment, PRD1a-1999. Similar requirements were adopted as ISO 15500-13 (2001). These PRD standards should be read in conjunction with the corresponding standards for CNG cylinders, ANSI/IAS NGV2 and ISO 11439, respectively. The ANSI standard deals with both burst disk type and thermal (fusible) type PRDs, while the ISO standard only deals with thermal and combination PRD systems containing both a fusible element and a burst disk.

The rate of failure of PRDs in Delhi buses is far higher than has been experienced in CNG bus fleets elsewhere

Both the ANSI and ISO cylinder standards require that cylinders specified for nominal 200 bar service be designed to accept overfilling to a "service" pressure of 260 bar. In the ANSI standard, burst-disk type PRDs are required to pass a number of tests, including cyclic pressure loading and chemical corrosion. After undergoing these tests, the PRD is required to burst at a pressure not less than 130% of the service pressure and not less than 75% or more than 105% of the activation pressure of a PRD that had not been subjected to these tests. Thus, the activation pressure for the PRD before testing would have to be at least 73% higher than the service pressure, or 2.25 times the nominal working pressure of the cylinder.

In discussions with representatives of the two major Indian bus manufacturers, we were given to understand that activation pressures for burst disks used on their buses are only about 30% above the nominal CNG working pressure. This means that the nominal fill pressure is within the range of burst pressures allowable after the cyclic loading and corrosion tests in the ANSI standard. Thus, it is not surprising that a substantial number of these disks are failing in normal use.

Since high temperatures can weaken a cylinder to the point that it fails even at normal service pressures, PRDs based on pressure alone does not provide complete

protection. For this reason, as well as the epidemic of burst disk failures, we recommend that all buses be equipped with thermal PRDs. However, these PRDs can also fail, especially when subjected to high ambient temperatures (e.g. exceeding 50°C) for long periods. Under these conditions, the fusible material in the PRD can "creep" until it fails. To reduce the possibility of problems in the future, we recommend that these replacement PRDs be required to meet ANSI/IAS PRD1 and 1a and/or ISO 15500-13, which include tests for this type of failure. PRDs qualified to these standards are required to pass accelerated aging tests equivalent to 20 years of operation at 57°C, and have demonstrated satisfactory service in buses even after prolonged service in hot climates, such as in Palm Desert and Sacramento, California.

Valve assemblies are often unnecessarily bulky and complex, as these are designed for industrial gas use

We were also informed that some vehicle operators have replaced the carefully-controlled "burst disks" with stronger disks that may not burst at the specified pressure. This allows them to fill more than the specified pressure, and thereby increase the driving range of the vehicle. This practice should be strictly prohibited, since it could lead to explosion of the CNG cylinders if the burst disk does not burst when needed. Replacing the existing burst disks with thermal PRDs would largely eliminate the motivation to tamper in this way.

The third significant cause of uncontrolled gas releases has been damage to the high-pressure piping or valves as a result of accidental impacts — such as with a roadside obstruction or another vehicle. Traffic accidents and driver errors can never be eliminated completely, but the probability of uncontrolled release of gas due to an accident can be reduced by appropriate design. For example, the chances of damage can be reduced by placing the CNG cylinders so that their vulnerable valve assemblies are located behind the cylinder, rather than ahead of it, and so that they project upward or inward rather than downward or outward. CNG valve assemblies used on buses in Delhi are often unnecessarily bulky and complex, as a consequence of originally having been designed for industrial gas use (see e.g. Figure 1 below). The use of valve assemblies designed specifically for use on vehicle fuel cylinders could reduce the number of components and joints (thus the potential for leaks) and the vulnerability of the system to damage from road hazards.

Figure 1: Cylinder valve and adapter assembly from a burned bus, broken by impact with a roadside boulder

4.3 Assuring Safety Over the Long Term

The existing fleet of CNG buses are primarily new vehicles near the beginning of their economic lives. As these vehicles age, it can be expected that they will develop additional safety problems, including problems due to leaks, corrosion, cyclic fatigue, accidental damage, and incorrect or improper repairs, to name only a few of the possible sources. Present CNG cylinders require periodic inspection and hydrostatic testing under the Gas Cylinder Rules. The ISO 11439 standard that we recommend does not require hydrostatic testing, but does require periodic inspection. It also sets a limit (typically 15 years) on the service life of any cylinder, based on its designed fatigue life. Because of the costs involved, many bus owners are likely to seek to avoid testing or replacing their CNG cylinders.

To combat these problems and assure continued safe operation of the CNG bus fleet, we recommend that the Government of the National Capital Territory take two key actions. The first of these is to set up an independent Safety Office, as already discussed above. This office, staffed by two or three qualified engineers and appropriate supporting staff, would monitor safety hazards and hazardous occurrences related to CNG and would carry out root cause analyses to determine the causes of these problems. It would identify the necessary corrective actions to the cognizant regulatory authorities, and then — a critical responsibility — would follow up to see that those actions are actually implemented. Thus, as new problems and hazards arise with the ageing of the CNG bus fleet, this office would be responsible for identifying them and checking that they are rectified.

Strengthen the present inspection process so that it includes an effective check of compliance with all safety standards – AIS 028

Our second recommendation for assuring the safety of CNG buses over the long term is to strengthen the present inspection process for commercial vehicles so that it includes an effective check of compliance with all CNG safety standards and regulations — and specifically with AIS 028. This check should be carried out before a bus is allowed to go into service, and every six months thereafter. This strengthened inspection process should be implemented as soon as possible in order to properly check and control the entry into service of diesel buses that have been converted to CNG. Our recommendations for strengthening the inspection process are given in more detail in Section 4.6.

4.4. Safety and Emissions Standards and Regulations

The use of CNG as a vehicle fuel in India dates to the beginning of the 1990's. Widespread use of CNG in Europe began about 50 years earlier in Italy, and some years later in the US. Today, CNG as a fuel for vehicle application is spread out on a commercial base all over the word, and as a result there exist numerous CNG safety regulations and standards applicable in various countries or regions.

National regulations cannot always be transferred from one country to another, especially if cultural conditions and usage differ greatly between the countries involved. International standards such as ISO standards are established by working groups or committees from many countries, and members of such groups are invited to comment on proposals before they are finalised. In the case of the ISO standards related to CNG, extensive testing was also carried out before the standards were established and made official. These standards are based in large part on the ANSI/NGV standards developed for the US and Canada, and incorporate much experience obtained from the widespread use of CNG buses in the U.S. Therefore, the use of the already established ISO standards is recommended also in India.

Already in the document AIS 024 D1, Annexure IV, safety checks are mandated as *"Safety Checks for use of CNG fuels in Internal Combustion Engined Vehicles & Indian Gas Cylinder Rules, 1981"*. The following summary shows the present status of the Indian standards for gas components. However, the regulation also opens up the possibility to consider other relevant national standards in special cases.

CNG Kit Component	Rules, Standard, etc
Cylinder	Gas Cylinder Rules, 1981
Fitment of cylinder on vehicle	AIS 028 D1, p 2.3, 2.5, 2.6
Cylinder valves	IS:3224 or Gas Cylinder Rules, 1981
Regulator	ISO-15500 or equivalent
Gas-air mixer	ISO-15500 or equivalent
Gas solenoid valves	ISO-15500 or equivalent
Filling connections (NZS & NGV-1)	AIS 028 D1, p 2.2.2 – 2.2.6
Ventilation	AIS 028 D1, p 2.4.2
Testing of conduit	AIS 028 D1, p 2.4.3.1
CNG fuel line	
a) High pressure – exceeding 100 kPa exc. 2.15 MPa	
— Rigid pipe	AIS 028 D1, p 3.1.1
— Flexible hose	AIS 028 D1, p 3.1.3.1, 3.1.3.2, 3.1.3.3.1
exc. 100 kPa and less than 2.15 MPa	AIS 028 D1, p 3.1.2
b) Low pressure – not exc. 100 kPa	AIS 028 D1, p 3.2.1 (a)
c) Joints and connections	AIS 028 D1, p 3.1.4.1, 3.2.1 (b)
Compartment/Sub-compartment	AIS 028 D1, p 2.4.1, 2.4.3.5
Safety checks for installation of CNG	Relevant paragraphs of AIS 028 D1

Public outcry against lax implementation of safety norms

AIS 028 D1 also refers to SAE, ASTM and ISO standards.

The present ISO standards (as of April 30, 2001) are the following:

On-Board CNG cylinders	
Gas cylinders – High pressure	ISO/DIS 11 439:2000

CNG gas quality	
Quality of natural gas for use as Compressed fuel for vehicles	ISO 15500-1:2001

CNG vehicle fuel system components	
General requirements and definitions	ISO 15500-1/DAM 1
Performance and general test methods	ISO 15500-2
Check valve	ISO 15500-3
Manual valve	ISO 15500-4
Manual cylinder valve	ISO 15500-5
Automatic valve	ISO 15500-6
Pressure indicator	ISO 15500-8
Pressure regulator	ISO 15500-9
Gas flow adjustor	ISO 15500-10
Gas/air mixer	ISO 15500-11
Pressure relief valve	ISO 15500-12
Pressure relief device	ISO 15500-13
Excess flow valve	ISO 15500-14
Gas tight housing and ventilation	ISO 15500-15
Rigid fuel line	ISO 15500-16
Flexible fuel line	ISO 15500-17
Filter	ISO 15500-18
Fittings	ISO 15500-19

CNG vehicle fuel systems	
Fuelling systems, Safety requirements	ISO/DIS 15501-1
Fuelling systems, Test methods	ISO/DIS 15501-2

Further there is continuous work going on to improve existing standards as well as to establish new standards.

Component	Draft standard/Proposal
Safety requirements for refuelling stations	CEN TC 326/WG1
Safety in natural gas filling operations	CEN TC 326/WG3
Fuelling connectors	ISO 14469, ISO 14469-2
Automatic gas injector	ISO 15500-7

At the latest meeting of the ISO subcommittee (April 2002) it was anticipated that all 19 parts of the CNG vehicle component standards, together with refueling connector standard, will be published by the end of 2002. At the same meeting, the ECE Regulation R 110 (Vehicles propelled by natural gas) was compared with present published ISO CNG vehicle/component standards and differences were detected. At the meeting the need to support the ISO standards with an appropriate rationale was agreed.

A comprehensive study of the differences between Indian standards and the established international standards is beyond the scope of this effort, nor can we offer any general opinion about the safety of the present Indian standards. However, the safety problems associated with present Indian practice concerning PRDs have already been discussed. Special concern should also be given to the standards for the gas cylinders installed on the vehicles. The present Indian Gas Cylinder rules dates back to 1981, and are essentially intended to address cylinders used for industrial gases. Many of the requirements established in these regulations are inappropriate for cylinders used in CNG fuel systems. These inappropriate requirements include the requirement for periodic hydrostatic testing, which entails that cylinders be removed from the vehicle in order to be tested. Such removal and replacement of cylinders in vehicle fuel systems should be avoided, as the cylinders may not be remounted adequately, and may come lose when the vehicle is in operation.

The existing gas cylinder rules may also fail to address some of the safety concerns associated with vehicle fuel systems

On the other hand, the existing gas cylinder rules may also fail to address some of the safety concerns associated with vehicle fuel systems. For example, industrial gas cylinders are commonly subject to only a limited number of pressurisation/ depressurisation cycles, whereas CNG cylinders in vehicles may be filled and emptied more than once a day. Thus, the requirements for cyclic fatigue resistance in CNG cylinders for vehicles may exceed those for industrial gas cylinders.

ISO standard 11439 is based on the NGV-2 standard developed by the International Association for Natural Gas Vehicles and the Natural Gas Vehicle Coalition in the US. It represents the distillation of nearly 50 years of experience with CNG use in vehicles, including satisfactory service in large numbers of urban transit buses. We recommend that India adopt regulations based on this standard for compressed gas cylinders used in motor vehicle fuel systems in place of the 1981 Gas Cylinder Rules

4.5. Conversion of Existing Buses

Indian requirements for vehicles operating on gas are established in the Central Motor Vehicle Rules issued by the Ministry of Road Transport and Highways. The

Burnt bus: Evidence of policy failure

seventh and most recent set of amendments to these rules were notified (published) in the Indian Gazette on November 19, 2001; and were to be effective six months later. One very important provision of these rules requires that CNG vehicles and kit components, including installation, comply with the Gas Cylinder Rules and with AIS 028 (Code of Practice for use of CNG Fuel in Internal Combustion Engined Vehicles). The rules also require that type approval be carried out in compliance with AIS 024 (Safety and Procedural Requirements for Type Approval of CNG Operated Vehicles).

Both AIS 024 and AIS 028 were developed by the Automotive Research Association of India (ARAI). ARAI is also the only test agency presently in operation in India with the authority to issue type approvals for vehicles or vehicle components where complete range of testing facilities are available. Type approvals are required both for new CNG and LPG vehicles, and for conversion of existing diesel or gasoline vehicles to use CNG or LPG.

The process to have a vehicle or a conversion kit type approved is briefly as follows:

1. A manufacturer or converter submits a bus to ARAI in Pune for approval
2. The vehicle is tested for emissions, safety and other related areas subject to regulation (heat build up, gradients, vibrations, strength of chassis etc).
3. ARAI issues the type approval certificate and the manufacturer could refer to the approval and release the product on the market.

The following regulations (including annexes) were provided to us for study during the visit:

Document	Description
AIS 024 D1	Safety and Procedural Requirements for Type Approval of CNG Operated Vehicles
AIS 028 D1	Code of Practice for use of CNG Fuel in Internal Combustion Engined vehicles
AIS 025 D1	Safety and Procedural Requirements for Type Approval of LPG Operated Vehicles
AIS 027 D1	Code of Practice for use of LPG Fuel in Internal Combustion Engine to Power 2 & 3-Wheeled Vehicles
AIS 026 D1	Code of Practice for use of LPG Fuel in Internal Combustion Engine to Power 4-Wheeled Vehicles

Since our present Scope of Work deals only with CNG, and especially buses, the LPG part of the regulations will not be discussed further. The related annexes to the regulation AIS 024 D1, are split up according to the following:

Annex	Description
Annex I	Technical specification of CNG kit
Annex II	Technical specification of the vehicle
Annex III	Checklist for fitness and certification for in-use vehicles
Annex IV	Safety checks as per AIS 028 D1, and
Annex V	Criteria to authorize the kit installer

According to regulation AIS 028 D1, consideration should be given to the possibility of decreased strength of the chassis when gas cylinders are installed on the vehicle, thereby increasing the weight of the vehicle and at the same reducing the load capacity (i.e. number of passengers). There are also other regulations to be considered and to verify (test) by ARAI during the process to have a CNG vehicle/engine or conversion kit type approved.

The notification from the Ministry of Road Transport and Highways specifies the emission limits to be fulfilled by new and converted vehicles. New gas buses are required to fulfil the Bharat Stage II requirement (corresponding to Euro II) and in-use converted buses are required to meet India Stage I requirements if manufactured before April 1, 2000 and Bharat Stage II requirements if manufactured on or after that date. Special consideration is given to calculating the emissions of NMHC (non-methane hydrocarbons) to compare with the set limit values. It should be noted that meeting the Bharat Stage II limits when the engine is new does not assure the long time durability of the concept. Thus, it is recommended to introduce Euro III or Euro IV emission requirements (including durability) for CNG buses as soon as possible. This was emphasised already in our first report.

The emission regulations also limit the CO content of the exhaust at idle to three percent by volume for vehicles other than two and three-wheelers. This is a much higher CO concentration that would be expected to occur in exhaust from the types of natural gas engines used in buses.

The notification by the Ministry of Road Transport and Highways contains a key paragraph stating that "Type approval for diesel vehicles retrofitted/modified for dedicated CNG operation shall be given for specific make and model of the vehicle in view of major changes or modifications involved in the CNG kit and diesel engine depending upon make and model of the vehicle". In the following paragraph, it is further explained that "CNG kit approved on the vehicle for specific engine capacity can be installed on the base model and its variants fitted with the same capacity engine".

The approval authority should issue guidelines on how to interpret current laws and regulations reducing the amount of testing

By various sources, it has been expressed that this regulation could be interpreted as requiring each and every model and variation of vehicle to undergo the whole test process to obtain a type approval certificate. We do not consider that this is necessary or desirable - in particular, we recommend that emissions certification of a particular CNG kit for a particular engine should apply to all applications of the same engine model in different vehicle types. Similarly, if a CNG engine demonstrates torque at least equal to that of the corresponding diesel engine, it should be accepted that the grade-climbing ability of the bus will be adequate.

The present wording in the notification may need further clarification, either by the Ministry or by ARAI. It is recommended that the approval authority, ARAI, should issue guidelines on how to interpret current laws, regulations and other relevant documents. This might also reduce the amount of testing for ARAI.

In the Ministry notification, it is also expressed that the following performance tests shall be carried out:

Test	Reference Document/Requirement
— Mass emission tests	MOST/CMVR/TAP-115/116 and relevant notifications
— Engine performance tests	IS 14599-1999
— Gradeability tests	Notification under role 124 of CMVR, 1989
— Constant speed fuel consumption test	IS 11921-1988
— Electro-Magnetic interference (EMI)	Notification under role 124 of CMVR, 1989
— Test of driving range	Min 250 km for buses
— Cooling performance	IS 14557-1998

In the notification (Annexure X) the responsibility of the different actors on the market is identified. Below is a short summary:

Responsibility of Test Agency:
— Carry out type approval of vehicles or components submitted by manufacturer according to the requirements
— Issue a type approval certificate when a vehicle meets the specified norms

Responsibility of Vehicle/Kit Manufacturer:
— Manufacture and supply vehicles/components conforming to the specification declared at the time of type approval
— Provide the vehicle owner with necessary owner's manual giving the instructions about periodic inspection, safety checks, and "dos and don'ts"
— Provide necessary tools and gadgets to carry out the installation, periodic inspection and maintenance
— Display, if needed on an appropriate location inside and outside the vehicle, additional safety instructions
— Strictly adhere to the maintenance schedule during the warranty period and give appropriate training to the users and if normal training is not sufficient arrange comprehensive training to the users
— Establish necessary infrastructure

The legal framework "formally" is in place. However there is need for improvements to the overall system for an acceptable level of quality

Responsibility of Owners/Users
— Be instructed by the supplier about the gas system and controls function in accordance with the owners manual
— Comply with given instructions for use and carry out the necessary periodic inspection
— Follow the instructions while filling gas and carry out leakage test periodically
— Insist on appropriate training given to drivers and technicians
— Carry out necessary repair and maintenance at authorized service stations
— Apply, within 14 days, to the concerned registering authority for alteration of the registration certificate

From reading the above regulations and applicable notifications the conclusion is that the legal framework "formally" is in place and the system for type approval and regular inspection of the gas installation could work very well together. However there is still need for essential improvements to the overall system in order to establish an acceptable level of quality and accuracy.

Recommendations

We noticed several drawbacks to the present system during our visit. Actions need to be implemented to improve the system. As examples of some measures that can improve the situation the following could be mentioned:

1. *Expand test resources at ARAI.* Since ARAI is the only appointed test authority for CNG buses, and has limited and over-stretched test resources located far away from the "CNG market", additional technical competence and test capabilities should be considered. However, there are plans to allocate additional test resources in the Delhi region to meet the demand from the market. This might also shorten the time for obtaining a type approval certificate
2. *Clarify the type approval regulations for vehicle conversions* in order to avoid misunderstandings. ARAI should issue guidelines on how to interpret the regulation and related documents, thereby making it more clear to the customers what they have to do and how testing and procedures should be carried out.

3. *Define responsibilities more clearly.* In a system for type approval it is essential to clearly define the responsibility for the different actors. This is partly done in the notification document, but nothing is explained about the obligations that must follow with a responsibility. For example: the presented documents do not explain what is the procedure if a kit supplier does not fulfil his obligations towards the vehicle owner. Can the kit supplier/installer lose his authorisation (requirement according to Annexure V of AIS 024 D1) to install conversion kits?
4. *Introduce a system for recall of issued type approval certificates.* A system of type approval must be always be linked to a system of withdrawal of type certificate when the certificate becomes invalid or if the product is no longer manufactured according to the specification given in the type approval documents. This essential part seems to be missing in the present system in India. During our visits to various players on the arena we noticed on several occasions that descriptions and procedures given in regulations were not fulfilled when vehicles were actually converted. As we presume that relevant regulations are fulfilled during the process of type approval, the only remaining cause for violating the regulation is that the manufacturer of the device is not following the given instructions and therefore the applicable type approval certificate should be withdrawn. (According to AIS 028 D1 paragraph 7.1 *"Prior to initial use, an inspection of the CNG system and components shall be carried out by, or under supervision of an Authorised Person/Installer, who shall also carry out a complete examination to ensure the system complies with all relevant sections of this Standard and any other statutory requirement as specified by the Central Government from time to time")*
5. *Introduce a system for feed back within concerned organisations.* Before a new bus or conversion kit can be approved for use it must undergo a process of type approval. Before a CNG bus is allowed in the streets of Delhi it must undergo a fitness-check. Unfortunately, there is no exchange of information between the organisations responsible for these two activities. Such contacts must be established. Today the fitness-check is more of "ticking" of items on a check-list instead of a thorough safety inspection. The inspectors at the Burari test centre do not really know what to check and how to assess whether a vehicle complies or has been converted in compliance with the corresponding type approval. A thorough review of all concerned organisations and enhancement of institutional arrangements must be carried out in order to make the introduction of CNG vehicles in Delhi a success story.

Today the fitness-check is more of "ticking" of items on a check-list instead of a thorough safety inspection

4.6. Fitness Inspections for CNG Buses

Before new vehicles or converted vehicles are allowed to be put in operation they must undergo an inspection called a "fitness-check". This inspection is performed at the Delhi Government's vehicle inspection centre in Burari. According to a document dated April, 2002 and issued by the Government of National Capital Territory of Delhi Transport Department, "*..inspection and certificate of fitness (COF) is mandatory for every transport vehicles at the time of registration, which is valid for two years from the date of issuance*". The COF must thereafter be renewed every year. 30 tests and checks are prescribed under the rules and should be checked visually and information (result) should be fed into a computer. The following tests are applicable:

i) Brakes
ii) Steering Gears
iii) Suspension
iv) Engine
v) Overall dimensions of the Vehicle

vi) Horn
vii) Lamps/Signals
viii) Chassis Embossing
ix) Speedometer
x) Paint
xi) Wiper
xii) Dimensions
xiii) Body
xiv) Fare Meter
xv) Electricals
xvi) Finishing
xvii) Road Test
xviii) Pollution
xix) Transmission
xx) Safety Glasses
xxi) Rear View Mirror
xxii) Spark Plugs
xxiii) High Tension Cable
xxiv) Head Lamp Beam
xxv) Other Lights
xxvi) Reflectors
xxvii) Silencers
xxvii) Dash Board Equipment
xxviii) Suppressor Cap.
xxx) Other

We are of the opinion that there is a big risk that it will take a long time until the automatic test lane is in operation again

When visiting the Burari inspection centre, we were informed that the operation was divided into two different sections. One section at the inspection centre was designed to carry out the fitness-check in an automatic (computerised) test lane and the other in a fully manual test lane with no equipment at all to test the bus. Unfortunately, the automatic mode was out of operation due to malfunction of some of the test instruments. Based on our experience and the type of failure we are of the opinion that there is a big risk that it will take a long time until the automatic test lane is in operation again.

As an average, there are about 80 buses coming to the centre for inspection every day. Some of the buses are brand new, while others are older converted buses. When the automatic test lane is in operation a random selection of buses are diverted to that lane; and of the 80 buses, 15-20 buses will undergo the computerised check. The automated inspection is divided into three operations, and instruments are available to test lights, brakes, speedometer, emissions (smoke from diesel engines) and wheel alignment. The test lane is operated by 9 technicians. Last month only seven (7) buses were checked on the computerised test lane due to malfunctioning equipment.

The rest of the buses undergo a manual “fitness-check”. As far as we were able to observe, no check was carried out on these buses — they more or less passed through the inspection line. During our short visit to the inspection centre we were given the opportunity to inspect the CNG installation on four buses, of which two were new and two were converted. On the new buses, we did not detect any alarming situation, and most probably the buses were in conformity with the type approval certificate.

On the converted buses the situation was completely different, and in our opinion neither of the buses should have been approved. However, we do not have any

information whether the buses were approved or not. The following severe divergences from the CNG safety regulation were apparent.

— Stress loops at the gas piping from the gas cylinder was missing (Figures 2 and 3)
— Piping from the gas cylinders was made using ?" pipes (instead of 1/4") (Figure 3)
— Clamping of gas pipes not sufficient in several locations (Figure 3)
— Distance between gas cylinder and exhaust muffler less than 75 mm and without a heat shield (Figure 4)
— Dust protection cap was missing at the gas filler inlet.

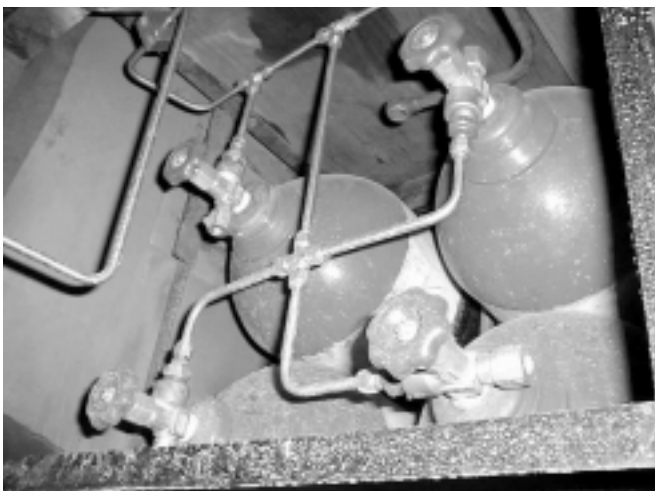

Figure 2: CNG piping on a converted bus, without stress relief loops

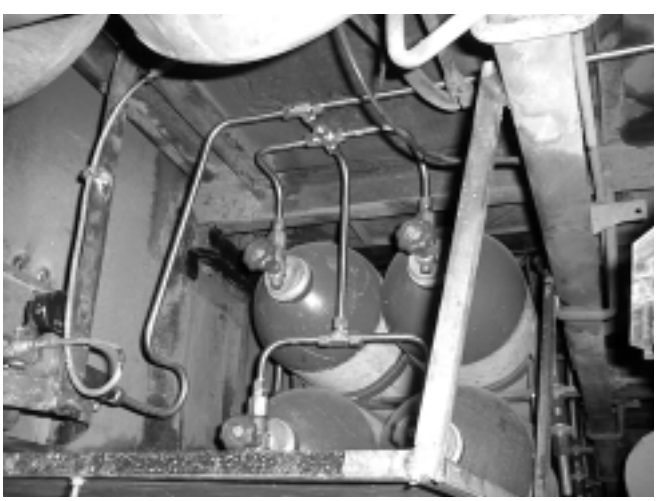

Figure 3: CNG piping on a converted bus, 1/2 inch diameter without stress relief loops, inadequate clamping of gas pipes

Figure 4: CNG cylinder on converted bus, less than 2 cm from exhaust muffler

Other problems were apparent on these converted buses as well. The size of the catalytic converter appeared inadequate for the size of the engine on both the converted buses, but we were unable to verify whether the catalyst installed corresponded with that specified in the type approval. It was also obvious that, on one of the buses, the rear brake on the right side of the bus was not working. This had to be pointed out to the inspectors, although the condition of the brakes is the number one item on the checklist.

We recommend against external PUC centres as it opens up too many possibilities for fraud by creative persons

As part of the "fitness-check", the emission performance should be measured. However, after a recent reorganisation, the exhaust CO content of the CNG fuelled buses is no longer measured at the Burari centre. The Burari centre only has the possibility to measure the smoke density from diesel vehicles (when/if the chassis dynamometer is in working condition, which is it not at present). During our visit we were shown statistics of measurements of 300 CNG buses carried out earlier at Burari inspection centre. Eighteen percent of the buses exceeded the limit value of 3 % CO by volume. Furthermore, this limit value is itself extremely lax, as a CNG bus with a properly-functioning air-fuel ratio control system and catalytic converter should not emit more than 1 % CO. In the statistics from the Burari centre, however, 40 % of the buses exceeded 1% CO. It was not clear to us whether the buses that exceeded the CO limit had actually been rejected or not.

The CNG buses still require a measurement of CO, even though the Burari centre no longer carries out this measurement. Instead, the buses go to a private Pollution Checking Centre, authorised by Department of Transport, Delhi to verify the idle emissions. After measurement, a protocol is issued and signed, and then submitted to Burari together with the bus for the "fitness-check". We recommend against continuing to rely on external Pollution Checking Centres for the CO measurement, as it opens up too many possibilities for fraud by creative persons. It is not clear whether there is a time limit on the validity of the measurement, nor is it clear whether the measurements at the Pollution Checking Centre are reliably accurate.
Based on the above, we strongly recommend bringing back the actual measurement of CO at idle for CNG buses to Burari. We recommend introducing a loaded mode test of NOx and CO for CNG buses, also to be carried out at the Burari inspection centre as soon as possible. The necessary steps should be taken to assure high

quality measurements, including training of personnel and proper calibration and maintainenance of the instruments. Recommended requirements for suitable emissions instruments for both idle and loaded modes are found below under the heading "*Instrumentation*"..

The present quality of the fitness-check is one of our biggest concerns. In our 2001 report, we strongly recommended that each and every converted bus should undergo inspection to assure that the CNG installation is safe and proper. Although the two major builders of bus chassis appear to have adequate quality control, the large number and varying quality of bus body builders suggest that new CNG buses should also be inspected after the body is installed to confirm that they still comply with CNG safety requirements — specifically AIS 028. In addition, the inspection should include checks of the CNG system for leakage, checks for compliance with CNG cylinder inspection and requalification rules, checks to verify that the present "burst disk" PRDs have been replaced with safer thermal models, checks to verify functionality of the emission control systems on the CNG buses, and any other inspection requirements identified in the course of the incident analyses performed by the safety office. These inspections should be performed both on new CNG buses and on in-use buses at the time of their annual renewal of the fitness certificate.

In order to fulfil this responsibility, the existing Burari inspection centre must be greatly strengthened. This will require more and better equipment, and extensive training for the inspection staff. In addition, and very importantly, the inspection staff must be provided with the leadership and political support to consistently reject vehicles that do not meet the specified standards and requirements.

The present quality of the fitness-check is one of our biggest concerns

In the following we provide some general ideas for an improved fitness-check carried out at the Inspection centre at Burari under operation of STA. It should be understood that these recommendations are very general. These general suggestions are based on long experience from vehicle inspection programs in Sweden and in international co-operation projects. These suggestions should be revised according to the local situation in each concerned country.

Inspection facilities

In order to carry out an inspection with a high quality the inspection centre must be in the possession of the necessary tools. Those tools include both the building itself in which the inspection is carried out, and also the instruments or equipment necessary to perform the inspection. In order to carry out an inspection of a vehicle it is essential that the layout of centre is suitable for its purposes. When and if new Inspection Centres are planned, it would be important to take advantage of the latest experiences from countries already well familiar with vehicle inspection of Heavy Duty Vehicles.

Instrumentation

The inspection at the computerized test line at Burari is divided into three different phases. For some of the operations instruments are needed. During our visit we noticed the following instruments:

- Test of lights
- Test of wheel alignment
- Test of brakes
- Test of speedometer and speedlimiter
- Test of smoke (from diesel vehicles)

During the process of inspection, the inspector was guided by a computer.

However, we do not know to what extent the results from the testing are stored in the computer. We strongly recommend that the results from all of the tests carried be stored in the computer system for later analyses and verification.

Since emission measurement is the main focus for the Fitness-check in the perspective of CSE, we summarize applicable experience from "tailpipe emission measurements below". ***For the future, we recommend to strengthen the emission test procedure for natural gas buses to include measurement of NOx and CO under loaded conditions on a chassis dynamometer.*** This will give a much better picture of the emission performance than the present idle test. Crucially for the natural gas buses, it will verify the functionality of both the catalytic converter and the closed-loop air/fuel ratio control.

In order to carry out tailpipe emission measurements at idle for gas buses an exhaust analyser must be available. The same type of exhaust analyser could be used when the inspection program is extended to also include loaded mode tests. It is adequate to specify an international standard that the instrument has to fulfil instead of appointing a specific make and model of instrument. The following remarks can be made related to the instrumentation.

The results from all of the tests carried out should be stored in the computer system for later analyses and verification

- The measurement system or analyzers must be certified or fulfil given standards
- The system or analyzer shall be able to print out the measured values
- It is recommended that the systems will store the measured data
- The system has to guide the inspector through the complete test
- Maintenance must be performed by a qualified person

In order to avoid contradictory requirements so that manufacturers and users of measuring instruments, test laboratories etc. may apply simultaneously the same standards, a world-wide organization has been established. The Organisation Internationale de Métrologie Légale (OIML) is an intergovernmental organization, with co-operative agreements between certain institutions (e.g. ISO and IEC), and whose main task is to harmonize regulations and standards.

One standard applies to measuring instruments that serve to determine the volume fractions of certain components of the exhaust gases from motor vehicles and establishes the conditions to which such instruments shall comply in order to meet any regulatory performance requirements within OIML member states.

The international recommendation OIML R 99, Edition 2000, a joint publication with ISO (ISO Standard 3930:2000); "Instruments for Measuring Vehicle Exhaust Emissions", specifies instruments intended for inspection & maintenance of in-use motor vehicles with 4-stroke engines. Three accuracy classes are covered: Classes 0, I, and II. Class 0 is the most accurate, and Class II the least. We recommend selecting instruments meeting at least accuracy class I. For future loaded-mode emission measurements, the analyser should be equipped to measure NOx emissions and to calculate the l-value (air/fuel ratio) as well.

In order to calibrate the instruments, calibration gases must be available and used regularly. OIML Class I and Class 0 instruments will not display readings unless they are properly calibrated beforehand.

Need for training of vehicle mechanics

In order to manage an enhanced system for the fitness-check it is important that the infrastructure in the country corresponds to the requirements that will be the result of the new programme. This will put an extra burden on the vehicle and component

manufacturer. In order to meet the demands for repair and service of the vehicles, the persons working in this field must be well educated and also given the ability to carry out the necessary repairs when vehicles are rejected after inspection. The responsible organisation for meeting those requirements must be the automotive and service industry. Each manufacturer must arrange for a proper education for persons within his organisation. The responsibility covers not only the technical parts of the vehicle and how to repair the vehicle, special attention must also be given to the instruments that must be used for the repair. When, for example, an exhaust emission analyser is required for tuning the engine, the manufacturer or the organisation must also be responsible for seeing that the mechanic will get the right education for the use of the instrument and also how the readings from the instruments are interpreted. It is also recommended to include some basic information about the working principle for the instruments as well as the relationship between engine-emissions-fuel consumption in a training programme.

Curriculum for vocational training

A very important part of any inspection programme is the education of persons performing the inspection. This is also closely related to the quality. The requirement for education is also a vital part of the process to be certified according to ISO 9 000. One example of a basic training program can consist of the following. The programme for overall training should be applicable to all instruments and procedures used at the fitness-check and in accordance with the checklist issued by the Government of National Capital Territory of Delhi Transport Department or any other appropriate check-list.

An important part of any inspection programme is the education of inspectors since it is closely related to the quality

- Every 36 month a special education including a test for approval
- Education centres (schools) must be certified
- Classes not more than 15 - 18 persons
- A plan for the education containing
- Knowledge about the regulation
- Technical knowledge of the concept
- Special technical facts
- Relationship between technology and emission
- Practical knowledge of the usage of the measurement system in theory and practice
- Practical knowledge how to carry out the program in theory and practice

Related to emissions, and in order to get a better understanding and also become more aware of the negative impacts of exhaust from combustion engines, more information is needed. It is not necessary that all persons involved in the Fitness-check will undergo the “second step” of education, but it is recommended that people in key positions participate. Such an education program can have the following contents:

- A general understanding of the effects on material
- A general understanding of the effects on crops, soil and water
- A general understanding of the effects on human health
- A general understanding of the effects on green house gases
- The relationship between fuel and emissions
- The difference between conventional fuels and alternative fuels
- Basic education in combustion theory for petrol and Diesel engines
- Drivers influence on emissions and fuel consumption

In order to have the possibility to further develop both measurement technology as well as knowledge it is of vital importance to enhance international co-operation.

From the long experience in countries already familiar with inspection processes it might then be possible to tailor-make detailed training schedules relevant to the local situation at the fitness-check carried out at Burari Inspection Centre.

The safety of the CNG fuelling system could be further improved through odorisation of the natural gas

4.7. CNG Fuelling Facilities

During our visit to Delhi, we visited several CNG fuelling stations together with IGL personnel, and observed a number of other stations in the course of our activities. During our visits, we saw little to indicate that the operation of the fuelling stations was unsafe, or that significant changes in fuelling practice would be advisable. To the contrary, the fuelling stations appeared for the most part well-managed, efficient, and safe.

One means by which the safety of the CNG fuelling system could be further improved would be through odorisation of the natural gas. At present, the only way to detect a gas leak is by the bubble method, or use of a methane detector, since unodorised natural gas cannot be detected by smell. Adding a distinctive odorant such as methyl mercaptan to the natural gas in the pipeline will make natural gas leaks much more obvious. This practice is almost universal among gas distribution systems, and we were informed by IGL that natural gas in Delhi will be odorised by the end of October, 2002.

A minor observation during our visits was that many fuelling attendants used the manual shut off system to limit the gas to the desired pressure in the cylinder instead of the pre-set automatic system. The reasons given varied from “because of limited quantities of CNG we have to shut off the filling process before the maximum pressure in the cylinders is reached” to “sometimes the driver would like to have some extra gas”. We recommend that the automatic shutoff systems be properly set and used for all filling. The only exception would be in a daughter station, where the pressure available in the cascade might be less than the pressure setting of the automatic shutoff.

The growth of CNG fuelling station capacity in Delhi has been truly impressive. To our knowledge, never in history has so much CNG compression and dispensing capacity been deployed in such a short time. The number of CNG dispensing stations in the Delhi region has grown to 94 as of May 31, 2002, of which 39 are connected directly to the gas line (mother stations and online stations), 26 are daughter-booster stations, and 29 are daughter stations without booster compressors. The main factor limiting the installation of additional on-line stations is the need to extend the gas pipeline system to additional parts of the city.

Because of the Honourable Court’s decision, the growth of demand for CNG in Delhi has been even more rapid than the growth of the supply. According to IGL, the total CNG compression capacity installed in Delhi is 656,000 kg per day, assuming that every compressor ran constantly 18 hours per day. The maximum daily sales to date has been 470,000 kg, and the average is about 410,000 kg per day, or about 60% capacity utilization. Because of the patterns of daily transportation demand, the demand for motor fuel is not evenly distributed throughout the day. For example, city buses normally operate 12 to 20 hours per day, and must refuel during the remaining hours. Given the distribution of motor fuel demand, the existing rate of compressor utilisation is extremely high, and it is therefore not surprising that long queues often develop at times of peak demand.

The existence of long queues for refuelling is undesirable for several reasons. First, these queues may interfere with traffic flow, creating congestion and hazardous

traffic conditions. Such conditions are especially likely where large vehicles such as buses mix with smaller vehicles such as taxis and three-wheelers. We recommend that buses, in particular, be served at bus-only stations wherever possible. IGL should also seek the cooperation of the traffic police to help ensure that queues are orderly and do not create unnecessary congestion or traffic hazards.

Another reason that queues are undesirable is that they are inefficient. The time that vehicles spend waiting to refuel is time that they cannot be providing transportation services, while the costs of the operator and the vehicle continue. This reduced vehicle productivity results in economic losses and reduces the quality of transportation service. This is a concern especially for public transit buses, since the Court's action to limit use of diesel buses already means that fewer buses are available for passenger service. We, therefore, recommend that IGL explore alternatives to queueing, such as establishing a regular, fixed "appointment" time for each public transport vehicle. At that time, the vehicle would have first priority for refuelling, without having to wait in the queue. By distributing these appointments among the available times and stations, IGL could better balance the demand on its capacity and reduce the total time spent in queues.

By distributing appointments for fuelling IGL could better balance the demand on its capacity reducing the total time spent in queues

As we pointed out in our last report, buses are the backbone of the public transport system, and should therefore be given priority of access to refuelling. In addition, taxis and three-wheelers can, if necessary, fall back on petrol operation, while buses cannot. With the recent Supreme Court order, fuel demand by privately-owned buses is expected to increase rapidly. We recommend that IGL devote every effort to accommodating this demand. Where possible, this should be done by setting up dedicated fuelling stations for buses only, where they would not need to mix with smaller vehicles. To improve the efficiency of utilisation of the buses and minimise the time they must spend in queues, IGL should establish a system of fixed fuelling times for each bus. Thus, instead of waiting in a queue for hours, buses could schedule their operations to arrive at the given station at a specified time, and be guaranteed refuelling at that time with only a minimal wait. The number of buses assigned to each time slot would be limited to those that the station could accommodate. This would greatly increase the efficiency of utilization of the buses, while helping to better distribute the demand on the fuelling station.

IGL presently has nine stations serving DTC depots, but more than 10 DTC depots presently lack CNG fuel. Buses from these depots must travel to another depot or a public fuelling station to refuel. This reduces their availability for public transportation. We recommend that IGL give high priority to providing every DTC depot with its own on-line refuelling station. Since these stations would be used mainly for refuelling buses during the night-time hours, consideration should be given to establishing public refuelling stations adjacent to the DTC depots. These public stations could take advantage of the excess compressor capacity available during the daytime to provide fuel to other classes of CNG vehicles.

5. CONCLUSIONS AND RECOMMENDATIONS

The following are the principal recommendations arising out of this study:

1. Replace the failure-prone "burst disk" pressure relief devices (PRDs) used on buses with devices meeting more appropriate design standards such as ISO 15500-13 or (preferably) the somewhat more rigorous requirements of ANSI/IAS PRD 1-1998. The PRDs should be installed and used in accordance with ISO 11439 or equivalent standards.

2. Establish an independent safety office in the Delhi Transport Ministry. This office should be charged with carrying out "root-cause" evaluations of CNG-related safety problems, identifying solutions, and following-up to ensure that these solutions are implemented.
3. Strengthen the vehicle inspection system of the Delhi State Transport Authority to carry out effective inspections of newly converted/built CNG buses before they enter service, and at six month intervals thereafter. The inspections should check compliance with the AIS 028 code of practice for CNG usage, especially the portions that deal with the installation and mounting of high pressure tubing and cylinders. They should check the CNG system for leaks, damage, and corrosion; and should verify emissions performance under load. These semiannual inspections should be supplemented by on-road checks. The STA inspectors should coordinate closely with ARAI to ensure that vehicle conversions and manufacture are carried out in accordance with the applicable type approvals.
4. Strengthen Delhi Transport Corporation (DTC) maintenance capability for CNG buses by providing gas detectors and staff training. Improve the safety and efficiency of present DTC operations by replacing failure-prone burst disks with improved pressure relief devices, and establishing CNG refueling facilities at all DTC depots.
5. Indraprastha Gas Limited (IGL) should continue to expand its refueling facilities, with special attention to the needs of public transport buses. With the rapid increase in the numbers of CNG buses, additional fuelling facilities for buses should be constructed. These should preferably be dedicated to buses only. IGL should work with the traffic police to control queuing practices and the traffic hazards due to queues backing up onto main roads. Queue management practices should be employed, such as establishing fixed "appointment" times for each bus to refuel. Odorisation of the gas in the distribution system should be implemented as quickly as possible.
6. Clarify and revise the type approval requirements for converted vehicles to avoid misunderstandings, and to eliminate unnecessary and duplicative tests. Expand test resources at ARAI to accommodate the remaining testing needs for type approval of vehicle conversions. Define more clearly the responsibilities of the owner, manufacturer, vehicle converter, and type-approval agency – especially the obligations of the vehicle converter to the vehicle owner for correct installation and operation of the CNG kit. Introduce a system by which type approval certificates can be cancelled, and recalls mandated, for converters and manufacturers who fail to meet their obligations, or where actual conversion practices do not accord with the type approval.

Queue management practices should be employed

6. ACKNOWLEDGEMENTS

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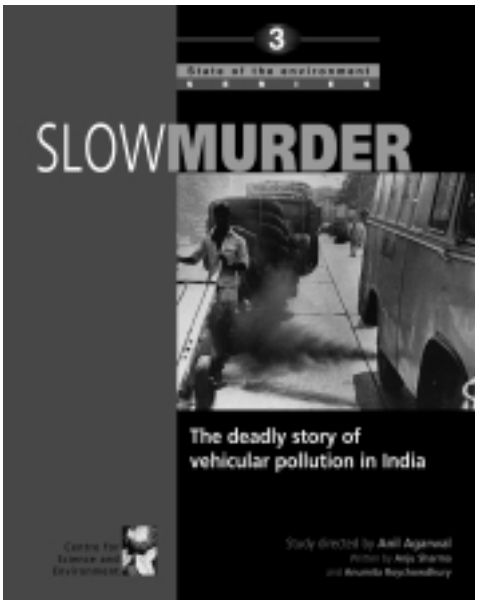

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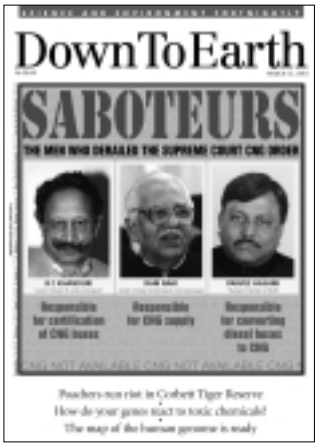

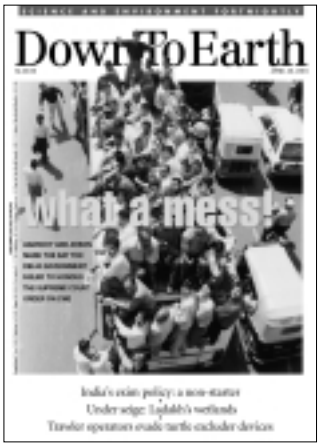

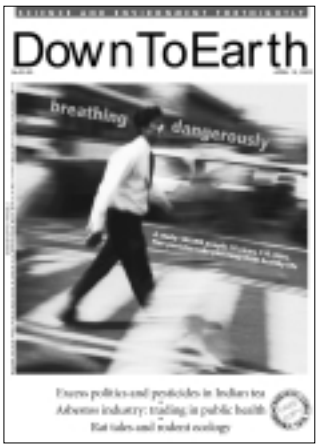

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